ECOLOGY OF *THESTYLUS AURANTIURUS* OF THE PARQUE ESTADUAL DA SERRA DA CANTAREIRA, SÃO PAULO, BRAZIL (SCORPIONES, BOTHRIURIDAE)

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ABSTRACT. Individuals of a *Thestylus aurantiurus* Yamaguti & Pinto-da-Rocha 2003 population in the Parque Estadual da Serra da Cantareira (São Paulo, SP, Brazil) show an increase of activity throughout the year. This increase is related to the reproductive season of these scorpions, from September to November. The abundance of scorpions was related to environmental factors in four different areas of the park. More scorpions were collected in the higher areas, far away from water sources of the park and not exposed to flooding. A short description of the *Thestylus aurantiurus* burrows is also presented.

Keywords: Scorpiones, *Thestylus aurantiurus*, Atlantic Rainforest, seasonality, relative abundance

Scorpions are extremely sedentary animals. According to Polis (1990a), they share the record with many spiders for the lowest arthropod metabolic rates ever recorded. Some species spend 97% of their lives inside their burrows, and they can exist one year without feeding (Polis 1990a). This is largely due to the "sit-and-wait" type of foraging activity adopted by most scorpions, which consists of being immobile and awaiting any prey that passes within reach. However, during the reproductive period, scorpions present certain behavioral changes. These changes occur mainly in surface activity, such as a reduction in female foraging activity and an increase in male surface activity in search of females (Benton 2001).

Courtship behavior is well-studied in scorpions. The behavior of 35 species of six families was described, from the about 1500 species and 16 families listed in Fet et al. (2000). The courtship behavior of many bothriurid species was studied, mainly by Peretti (1995, 1997). However, there are few works on the reproductive activity of scorpions. Peretti (1997) studied the reproductive characteristics of Argentinean scorpions, describing the reproductive period, interval between mating and litter birth behavior, and period of litter birth of some bothriurid scorpions. Matthiesen (1968) studied the courtship behavior of certain Brazilian scorpions during courtship, e.g., *Bothriurus araguayae* Vellard 1934.

The genus *Thestylus* Simon 1880 has been little studied due to its restricted geographical distribution and low abundance. The only study on the reproduction of *Thestylus* was Machado & Vasconcellos-Neto (2000). They described the courtship behavior of *T. aurantiurus* Yamaguti & Pinto-da-Rocha 2003 (mentioned as *T. glasioui* (Bertkau 1880)). According to the authors, the reproductive period is very seasonal, occurring during the hot and wet season (beginning in October), in Serra do Japi (23°17′S; 47°00′W), Jundiaí, SP, Brazil.

Abundance and its relationship to environmental factors is another well studied aspect of scorpion ecology. Evidence suggests that scorpions are selective when choosing a place to build their burrows. Polis & McCormick (1986) studied desert scorpions and noticed differences of abundance among the species related to the environment. Höfer et al. (1996) presented a study relating environmental aspects of different habitats of a Central Amazon Rainforest with the relative abundance of a certain scorpion species. Koch (1977, 1978) studied burrows in the genus *Urodacus* Peters 1861 (Urodacidae), observing a different kind of burrow for each *Urodacus* species and verifying that environmental aspects influence burrow site location.

The study presented here was conducted to assess the activity of a population of *Thestylus aurantiurus* (Figs. 1 & 2) throughout the course of one year (February 2000–January 2001), and the relationship between relative abundance and environmental aspects in Parque Estadual da Serra da Cantareira, São Paulo, SP, Brazil.

METHODS

Studied area.—Collections were made throughout one year in four areas of the Atlantic Rainforest. These areas are located in the Núcleo Pedra Grande of the Parque Estadual da Serra da Cantareira (23°22′S; 46°36′W), São Paulo, SP, Brazil, in a project conducted together with Universidade Bandeirante de São Paulo (UNIBAN).

Area 1 named Pedra Grande (23°26′30″S; 46°38′20″W at an elevation of 1050 m), possesses dense vegetation, and well-developed small and medium-sized understory strata, with lianas and bamboo groves. In area 2, named Lago das Carpas (23°25′40″S; 46°36′06″W, 700 m) possesses dense understory, with flooded areas and bamboo groves. Area 3 named Divisa (23°25′48″S; 46°38′00″W, 1050 m), is located on the boundary between the municipal districts of São Paulo and Mairiporã. It possesses dense vegetation, with numerous lianas and some exotic species, such as *Pinus* sp. Area 4, named Sede (23°27′03″S; 46°38′06″W, 650 m), is characterized by lush vegetation, with steep slopes, many lianas, a large amount of low vegetation and flooded areas.

The values of monthly median temperatures and monthly total rainfall presented in this work were supplied by the Companhia de Saneamento Básico do Estado de São Paulo (SABESP). These data were recorded at Paiva Castro's dam (23°22′11″S; 46°40′07″W), in the municipal district of Mairiporã, near to the Parque Estadual da Serra da Cantareira.

Ecological samplings.—Twelve monthly collections, of nine days each, were undertaken between February 2000 and January 2001. Scorpions were collected in drift fence pitfall traps (Fig. 3). Traps were composed of groups of four buckets of 20 L each, buried with the opening nearby ground level, arranged in a "Y" shape. Each "arm" of the "Y" was 5.0 m from the central point. One bucket was buried at each tip of the "Y" and one at the central point. Strips of canvas of 5.0 × 0.5 m, fixed with wooden stakes, connected each outlying bucket to the central one in order to steer the animals into the buckets. Ten traps were placed in each area, comprising a total of 40 buckets per area. The central point of each trap was 20 m from the next in a straight line. The bottom of each bucket was perforated to prevent the accumulation of rain water. The size of the holes prevented the animals from escaping.

Traps were checked every morning and covered on the last day to avoid captures outside the sampling period. Each trap was numbered individually, enabling the identification of scorpions according to trap, date and collection area. Since the traps were originally erected to capture small mammals alive, a preserving liquid was not used, hence animals remained alive until the moment of capture. Thus, there was a possibility of the scorpions having been devoured by toads, lizards or rodents inside the buckets. So, the number of collected scorpions may be higher than the observed. However, the results probably would not change, because the patterns of seasonality are clearcut in this work.

This kind of sampling probably produced a different result from active collection (e.g. with ultraviolet light), but with pitfall traps, the seasonality would be more evident. Pregnant females were identified according to Farley (2001), with dissections and observation of the ovariuterus, and comparison with Farley's photos. Voucher specimens were deposited in Museu de Zoologia da Universidade de São Paulo (MZSP), São Paulo, SP, Brazil.

Environmental data.—The following environmental data were gathered: amount of litter, density of the canopy, perimeter of closest 10 trees measured at the breast height (PBH), soil composition and elevation. All these data were recorded on the same day, in May 2002 (subsequent to the period of collection), close to the places where traps were located. The amount of litter of an area of 0.25 m^2 was measured. Ten samples were collected randomly in each area totaling 40 samples. Each sample was placed in a stove for 48 hours and its weight was measured soon after. The density of the canopy was measured using a densiometer at 24 points in each area, totaling 96 samples. The PBH was measured at 24 points in each area, totaling 960 trees. To analyze

Figure 1, 2.—*Thestylus aurantiurus*. 1. Male. 2. Female.

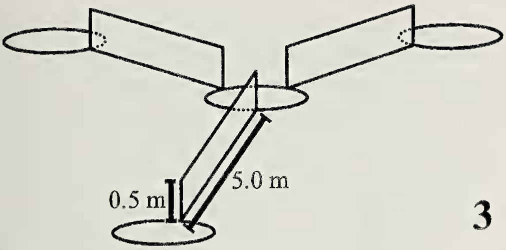


Figure 3.—Schematic representation of the drift fence pitfall traps used in sampling in P. E. Serra da Cantareira, Brazil.

soil composition, samples were collected at 8 points in each area, totaling 32 samples. The percentage of organic matter and the vegetational covering were measured.

Statistical analysis.—In the statistical analysis of the number of animals collected in each area and to verify whether environmental factors differ in the four areas, the Kruskal-Wallis test was utilized with $\alpha = 0.05$. For a comparison between the number of animals collected in the higher areas and the number of animals collected in the lower areas, a Mann-Whitney test was used with $\alpha = 0.05$. Before those statistical analysis, the normality and the homogeneity of variances were tested. The data were ranked in both cases. In order to verify whether there is a relationship between these factors and the number of collected animals in each area, the Spearman Rank Correlation was utilized with $n = 4$.

RESULTS

Burrows of *Thestylus aurantiurus*.—Individuals of *T. aurantiurus* in Parque Estadual Intervales (São Paulo, SP, Brazil) were observed foraging at the entrance of their burrows, in ravines near river margins, with pedipalps and anterior body outside (G. Machado, pers. com.), in a typical sit-and-wait foraging type. Burrowing activity of *T. aurantiurus* was observed in captivity, where all individuals constructed many burrows, apparently looking for the best place to stay. The burrows were simple, with a single vertical or oblique tunnel (1.5–3.0 cm deep), and a horizontal region at the end (about 1.5 cm long). The entrance could be circular or semicircular in shape, with 1.0–1.5 cm of maximum width.

Seasonality.—*Thestylus aurantiurus* was the only scorpion species recorded in the park. Between January (summer) and July (winter), few individuals were collected (from 0–2 scorpions/month in 40 traps). Four males were collected in August. In the three subsequent months (spring), 18, 36 and 11 scorpions were collected, respectively (about 80% of the total sampled). Twelve females were collected in October (about 70% of the total sampled females). In the remaining months of the year, one female was the maximum number captured per month (Fig. 4).

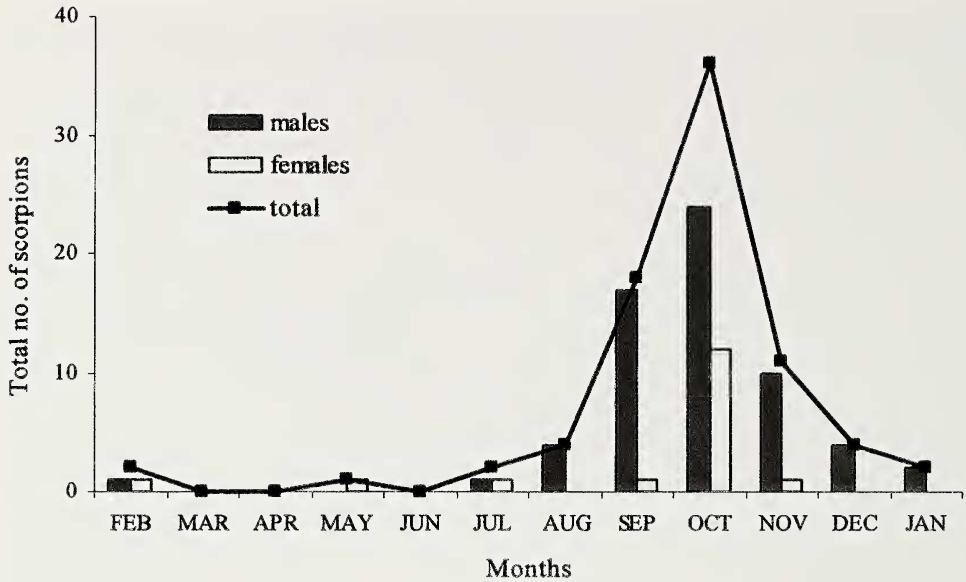
Four pregnant females were found in October and one pregnant female in November 2000. No fecund females were found in the other months.

Relative abundance in four areas.—The individuals collected possessed a heterogeneous distribution in the four areas (K.W., $H = 14.966$; $P = 0.002$). The number of individuals collected in the two higher areas (1 & 3) was significantly higher than the number of individuals collected in the two lower areas (2 & 4) (Mann-Whitney test, $U = 79.500$; $P = 0.001$).

The amount of litter was different in the four areas (area 1 = 166.9 g, area 2 = 339.1 g, area 3 = 190.5 g, area 4 = 132.7 g; K.W., $H = 18.00$; $df = 3$; $P = 0.0004$; $n = 40$), but only area 2 presented a different amount of litter, the amount of the other three areas are very similar (according to the Tukey HSD test). Canopy density was different in the four areas (area 1 = 4.625, area 2 = 8.5, area 3 = 8.71, area 4 = 9.92; K.W., $H = 22.46$; $df = 3$; $P < 0.0001$) but it was not related to the number of scorpions collected ($r_s = 0.40$; $n = 4$; $P = 0.60$). The PBH was also different in the four areas (area 1 = 14.09 cm, area 2 = 18.25 cm, area 3 = 16.9 cm, area 4 = 18.86 cm; K.W., $H = 18.81$; $df = 3$; $P = 0.0003$) but not related to the number of scorpions collected ($r_s = 0.21$; $n = 4$; $P = 0.79$). Soil type was the same in the four areas. The number of scorpions collected was not significantly related to the elevation ($r_s = 0.74$; $n = 4$; $P = 0.26$). Air temperature and rainfall were not related to abundance, although the number of scorpions increased immediately after the coldest month.

DISCUSSION

Reproductive activity.—The population of *Thestylus aurantiurus* in the Parque Estadual da Serra da Cantareira presents differentiated activity throughout the year suggesting the ex-



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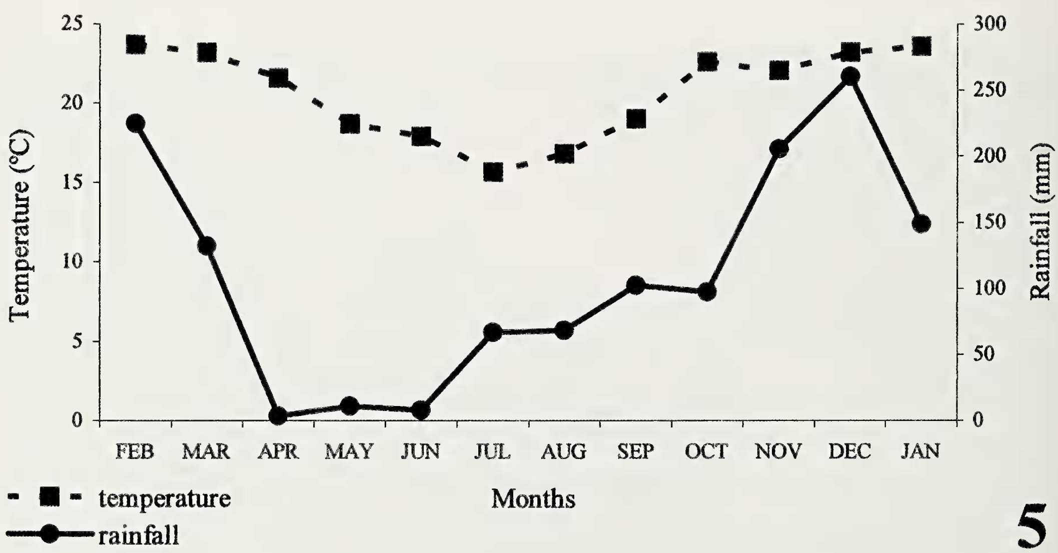

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Figures 4, 5.—4. Seasonality of the scorpion population of P. E. Serra da Cantareira, Brazil (February 2000–January 2001), with the total number of individuals collected by month. The columns represent the number of males and females collected by month. 5. Means of temperature (in °C) and total rainfall (in millimeters) by month in the P. E. Serra da Cantareira, Brazil (February 2000–January 2001).

istence of a reproductive season. The reproductive season lasts from September to November, with an activity peak in October (Fig. 4), in the beginning of the hot, wet season (Fig. 5). This can be evidenced by the fact that fertilized females were found in October and November of 2000.

Ten of the 12 females collected in October were collected together with males. These females may have fallen into traps while they were dancing with males in search of a place to deposit the spermatophore. The sit-and-wait foraging strategy of this species consists of remaining immobile, waiting for prey. This foraging strategy type does not require the scorpion to move around (Polis 1990a), leading us to conclude that most of scorpions collected in this study were in a search of partners and not prey.

Corey & Taylor (1987) collected scorpions in pitfall traps, close to Orlando, Florida, U.S.A. during one year, sampling every two months. Only one species was collected, the buthid *Centruroides hentzi* (Banks 1900). This is an errant forager but also presenting an increase in activity throughout the year, in July and September, apparently during the reproductive period.

The reproductive period in scorpions varies according to the species. Some South-American scorpions such as *Tityus bahiensis* (Perty 1833) do not exhibit a well-defined reproductive period, instead remaining active throughout the year (Matthiesen 1968). There is information on several species of the Bothriuridae. The reproductive period of *Bothriurus bonariensis* (C.L. Koch 1841) is from November to February, *B. flavidus* Kraepelin 1911 from November to January, and *Urophonius iheringii* Pocock 1893 and *U. brachycentrus* (Thorell 1876) from May to September (Peretti 1997). However, differences in the *Thestylus aurantiurus* reproductive period may be related to climatic differences at the different localities. The beginning of the reproductive period of the Argentinean species of *Bothriurus* coincides with the beginning of the local warm, wet season (Peretti 1997). This also occurs in the *T. aurantiurus* population of the Parque Estadual da Serra da Cantareira and the Parque Estadual da Serra do Japi (Machado & Vasconcellos-Neto 2000). For these populations, the beginning of the reproductive period is September to October.

There is a great difference in activity between the sexes in the *Thestylus aurantiurus* population of the Parque Estadual da Serra da Cantareira. Many more males were captured than females (Fig. 4), probably due to the increase of male activity during the reproductive period. Females wait for males close to their shelters, which thus explain this low occurrence (Benton 2001).

The collection using pitfall traps produce a different result from active collection with ultraviolet light. Individuals standing still are also found with active collection. If ultraviolet lights were used, the expected number of captured scorpions would be higher and the expected number of females would be closer to the number of males (since the sex ratio of *Thestylus aurantiurus* is 1:1). However, seasonality of activity probably would not be as evident as in the collection with pitfall traps. We conclude that the population of *Thestylus aurantiurus* in the Parque Estadual da Serra da Cantareira possesses a reproductive season from September to November (Fig. 4).

Influence of environmental factors on abundance.—Individuals of the *Thestylus aurantiurus* population from the Parque Estadual da Serra da Cantareira apparently prefer places at a higher elevation. This can be related to the possibility of shelters in lower areas being flooded in the rainy season. The two areas with a higher number of collected scorpions (1 & 3) are located at a higher elevation and farther from water sources. On the other hand, the two areas with fewer collected scorpions (2 & 4) are located in places at a lower elevation. These areas are close to water sources, becoming flooded in the rainy season.

According to Polis (1990b), some scorpion species seek specific environmental conditions in which to build their burrows. Namibian scorpions use several places as a shelter including simple holes in the soil and under tree barks (Lamoral 1979). Harington (1978) verified that *Cheloctonus jonesii* Pocock 1892 (Liochelidae) examines a large area before beginning to dig its burrow. Additionally, in *Urodacus* there are differences among species in the choice of place, format and structure of burrows (Koch 1978).

Many researchers verified the preference of scorpions for higher elevation localities that do not flood and are far from water sources. Williams (1966) observed that burrows of *Anuroctonus phaeodactylus* (Wood 1863) (Iuridae) are located on steep slopes, their entrances being counter to surface water flow. These burrows are rarely located on the bottom of valleys, in the lower regions of drainage. Zinner & Amitai (1969) verified that two species of *Compsobuthus* Vachon 1949 (Buthidae) of Israel migrate to higher places during the rainy season. The entrances to their burrows are also built to avoid the accumulation of rain water. Koch (1977) also observed that several species of Australian scorpions build their burrows only on slopes or where rain water does not accumulate. The individuals of *T. aurantiurus* studied in this work were more abundant in places at a higher elevation. These places are sloping, do not flood and rain water does not accumulate.

ACKNOWLEDGMENTS

We thank Sergio A. Vanin, head of Departamento de Zoologia of Instituto de Biociências of Universidade de São Paulo during 2003, when this study was carried out. We thank the colectors of UNIBAN: Arlei Marcili, Caroline C. Aires, Cristiane Fojo, Domenica Palomaris, Fernanda A.N. Bastos, Fernanda Martins, Kátia Brózios, Laerte B. Viola, Marcelo Timóteo, Patrícia B. Bertola, Roberta Pacheco, Sandra Favorito and Sidney F. A. dos Santos. We thank Gustavo E. Kaneto, Flávio H.S. dos Santos, André do A. Nogueira, Alexandre Albuquerque da Silva, Alexandre C. Martensen, Felipe B. de Oliveira, Rodrigo H. Willemart for help in statistical analysis and Glauco Machado for help in statistical analysis and personal communication. We thank Dalmo do V. Nogueira Filho, president of SABESP, for supplying the data of rainfall and temperature. We thank Thayná J. Mello for assistance in language translation of the manuscript. We thank Glauco Machado and Alfredo V. Peretti for assistance and revision of the manuscript. We also thank the other members of LAL: Ana Lúcia Tourinho, José Paulo L. Guadanucci, Marcio B. da Silva, Marcos R. Hara and Sabrina O. Jorge for assistance in completing this project.

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Manuscript received 30 June 2004, revised 26 January 2005.